RESEARCH NOTES
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ShakeMap and GIS Technologies Demonstrated to Expedite Caltrans' Earthquake Response

RESULTS: Caltrans' GeoResearch Group is facilitating technology transfer of new GIS procedures utilizing *ShakeMap* to aid earthquake response. *ShakeMap* is a map of shaking intensity developed directly from recordings that is available via web within 5 to 10 minutes of an earthquake. The new procedures will assist response managers in focusing field inspection resources on the most severely shaken areas.

Why We Pursued This Research

Following a major earthquake, one of the most critical tasks for the Department is to rapidly assess the condition of all bridges and roadway corridors in the State highway system. Timely response is important to ensure public safety, aid routing of emergency vehicle traffic, and (re-) establishment of critical lifeline routes.

Figure 1 – Damage to the I5-SR14 Interchange following the 1994 Northridge earthquake.

The primary method for these assessments is a thorough onsite inspection by trained personnel from Maintenance and Structures. However, procedures used in the past for establishing inspection priorities were relatively unfocused due to lack of precise information about the distribution of damaging levels of shaking. In the absence of such information, the practice had been to use the epicenter location (available from the REDI/CUBE system immediately after the earthquake), find the closest fault, and develop a list of bridges within a specified buffer zone surrounding that fault. Maintenance crews were dispersed widely within that region to perform initial reconnaissance.

The problem with epicenter-based or whole-fault based buffer zones is that earthquake shaking levels vary dramatically within the buffer zone. An earthquake rarely ruptures over the entire mapped fault length. Furthermore, ground shaking at the same distance from a rupture zone varies by nearly a factor of 10 due to a variety of seismological and geotechnical effects including *fault rupture directivity*, *deep basin effects*, and *local site response*. Buffer zones large enough to account for all areas that could be strongly shaken will include wide swaths of undamaged zones, thus diverting inspection resources away from critical needs.

New technologies to rapidly process field earthquake recordings have evolved over the past several years. *TriNet*, a partnership between Caltech, the U. S. Geologic Survey, and the California Geologic Survey, has developed a series of *ShakeMaps* that present intensity of ground shaking based upon measurements from instrumented sites. These maps are now made available throughout the state by the California Integrated Seismic Network (CISN) via web and in a GIS format within 5 to 10 minutes following an earthquake. The color-contour base map in Fig. 2 shows an example *ShakeMap* for the 1994 Northridge earthquake.

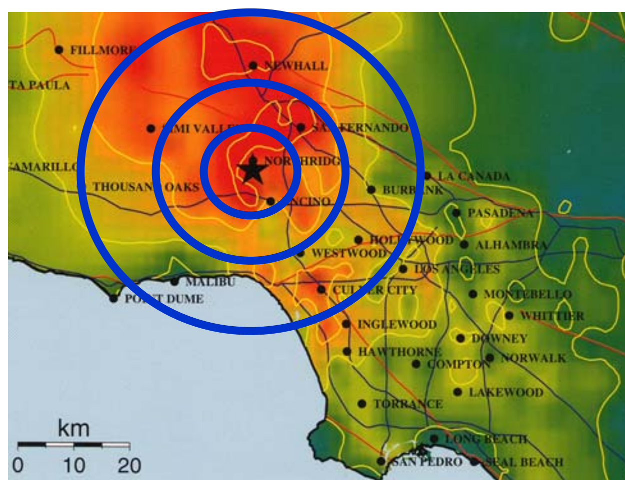

Figure 2 – Magnitude of ground shaking from the 1994 Northridge earthquake

Figure 2 also shows a comparison of ground shaking based upon a simple buffer zone surrounding the Northridge epicenter (blue concentric circles) versus ground shaking based upon *ShakeMap* (red to green contoured areas). This figure clearly shows much greater shaking intensity to the north than the south (because of rupture directivity effects). It also shows relatively isolated "hot spots" of shaking near Santa Monica (possibly due to basin edge effect) and near Culver City (likely due to local site response effect). Had it been available at the time, *ShakeMap* could have immediately focused inspection resources not only near the epicenter, but also northward toward Newhall and to the isolated areas to the south near the I-10 collapses at La Cienega and Fairfax Avenues.

What We Did

The GeoResearch Group recognized that a more effective method for prioritizing earthquake response was possible using *ShakeMaps* and the GIS data and technologies already in place within the Department. As our bridge inventory is also available in a GIS format, we pursued an approach to combine the two data sets to deliver a more useful combined map.

A preliminary rating scale was devised to simply categorize bridges based upon the year of construction, which resulted in a crude translation of susceptibility to damage from ground shaking. This proposed rating scale, combined with *ShakeMap* shaking intensity, was used to create a map of the impacted zone. Red regions denote "*severe damage possible (all bridges)*," yellow regions indicate "*severe damage possible (all bridges constructed before 1975)*," green regions correspond to "*some damage possible*," and clear regions indicate "*damage unlikely.*" A map using this rating scale for the 1994 Northridge earthquake is shown in Figure 3. Generally, these zones correspond reasonably well with observed bridge damage.

A simple GIS routine was also developed that allows the map and bridge data to be analyzed and quickly converted into a priority list, as shown in Figure 4. This table lists bridges within the affected region sorted by damage potential, route, and postmile to aid in the dispatch of inspection personnel. Other parameters on the list include geodetic coordinates and shaking intensity at that location.

The GIS tools developed for this application are now fully functional and are currently being tested by clients in Structures Maintenance and Investigations and Engineering Services. To date, feedback on this tool has been very positive. Additional functions have been requested including enhanced automation, internet dissemination, electronic field data collection and exchange for reconnaissance. The *CISN* has also expressed strong interest in pursuing more advanced applications of *ShakeMap* within Caltrans and more robust delivery mechanisms.

The Researchers Recommend

This simple GIS tool, in its current state of development, takes a more rigorous approach to identifying potentially damaged bridges and routes following an earthquake than methods previously employed by the Department. In practice, the tool generates more detailed information and is faster than previous procedures. The GeoResearch Group strongly recommends using the *ShakeMap*-based approach.

Additional practical research using data developed through the bridge retrofit program is needed to refine the preliminary bridge rating scale and thereby yield a more accurate and focused inspection prioritization scheme. Further functional enhancements to the tool are also needed to make it easier to use with less GIS training, and more readily accessible using internet, and possibly wireless technologies.

For More Information About This Research

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URL at USGS for *ShakeMap*:

http://earthquake.usgs.gov/shakemap

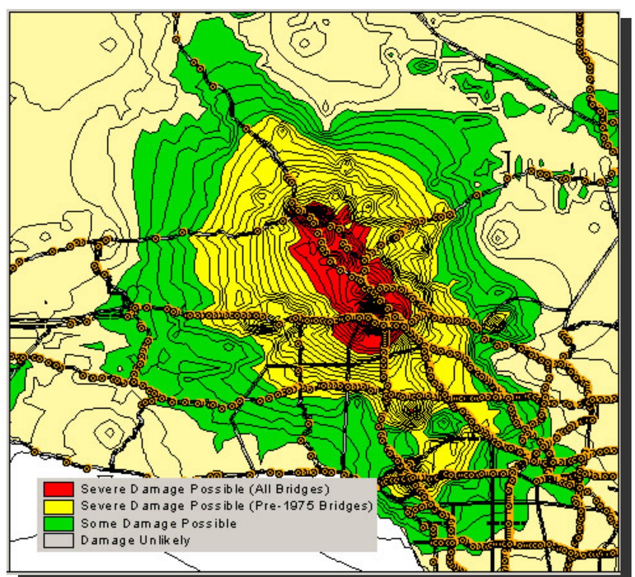

Figure 3 – Potential bridge damage assessment using ShakeMap and the GRG's GIS analysis method

Bridge Name	Bridge No.	PM	latitude	longitude	Dist	Co	Rte	SA (1s)	Potential Damage Status
ALISO CR CULVT	53 2634	R6.38	34.2683	-118.5183	7	LA	118	1.04	Severe Damage Possible (All Bridges)
CHIMINEAS AVE OC	53 2512	R6.23	34.2683	-118.5167	7	LA	118	1.04	Severe Damage Possible (All Bridges)
ETIWANDA AVE POC	53 2511	R6.03	34.2700	-118.5267	7	LA	118	1.00	Severe Damage Possible (All Bridges)
RESEDA BLVD OC	53 2510	R5.81	34.2767	-118.5300	7	LA	118	1.00	Severe Damage Possible (All Bridges)
WILBUR AVE OC	53 2509	R5.2	34.2750	-118.5450	7	LA	118	0.96	Severe Damage Possible (All Bridges)
TAMPA AVE OC	53 2647	R4.64	34.2733	-118.5467	7	LA	118	0.88	Severe Damage Possible (Pre-1975 Bridges)
LIMEKILN CANYON WA	53 2502S	R4.6	34.2667	-118.5483	7	LA	118	0.88	Severe Damage Possible (Pre-1975 Bridges)
LIMEKILN CANYON WA	53 2502K	R4.54	34.2667	-118.5483	7	LA	118	0.88	Severe Damage Possible (Pre-1975 Bridges)
HADDON AVE PUC	53 2175	R11.9	34.2683	-118.4350	7	LA	118	0.88	Severe Damage Possible (Pre-1975 Bridges)

Figure 4 – Portion of priority list based upon GIS analysis